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WATER QUALITY IMPACTS OF STORMWATER-ASSOCIATED CONTAMINANTS: FOCUS ON REAL PROBLEMS

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ABSTRACT

Water pollution control agencies are implementing control programs for chemical contaminants in urban stormwater runoff because concentrations of total forms of some contaminants in receiving water exceed numeric water quality standards. While some assert that stormwater-associated contaminants are causing water quality problems (impairment of beneficial uses), there are significant reasons to question the reliability of that claim. While urban stormwater runoff frequently contains many chemicals in sufficient concentrations to cause exceedance of numeric US EPA water quality criteria in receiving waters, exceedance of a water quality criterion/standard applied to total concentrations is not a demonstration of water quality impairment. The US EPA water quality criteria were developed for worst-case or near-worst-case exposure to available forms of the contaminants. Such exposure conditions would not be expected with short-term, episodic runoff events. Substantial portions of many of the chemical contaminants in stormwater runoff are associated with particulates and would hence be expected to be largely unavailable to affect aquatic life-related beneficial uses of receiving waters. Furthermore, evidence of beneficial use impairment caused by urban stormwater runoff has not been forthcoming to document the claims. It is concluded that many of the contaminants associated with urban stormwater runoff from residential and commercial areas do not impair beneficial uses of receiving waters. The current US EPA water quality criteria have limited applicability to assessing potential water quality concerns for stormwater runoff. Guidance is presented on how urban stormwater runoff-associated contaminants should be evaluated and regulated to control use impairment without significant unnecessary expenditures for contaminant control.

KEYWORDS

Urban Stormwater; pollution; toxics; heavy metals; nutrients; non-point sources; study approach; US EPA criteria; water quality standards; Clean Water Act.

INTRODUCTION

The 1987 Amendments to the Clean Water Act required the US EPA to develop NPDES permit application requirements for "Phase I" classes of stormwater discharges. "Phase I" dischargers included cities with populations greater than 100,000, selected industrial sources, and special sources that contribute to violations of water quality standards. Statutorily excluded were agricultural stormwaters, irrigation return flows, and uncontaminated runoff from oil and gas or mining operations, owing to political considerations or coverage under other regulations.

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Accordingly, in November 1990, the US EPA promulgated regulations intended to control the pollution of the nation's waters by contaminants in "Phase I" discharges (US EPA, 1990). While it has been known since the 1960s that stormwater runoff from urban, industrial, and rural areas typically contains elevated concentrations of a wide variety of contaminants that could cause water quality impairment, until November 1990 little was done by federal or state water pollution control agencies to develop control programs for contaminants in such runoff.

The US EPA's efforts toward controlling potentially toxic chemicals in surface waters has shown that many surface waters downstream of urban areas contain heavy metals and a number of other potentially toxic chemicals in concentrations above the US EPA water quality criteria and state standards numerically equal to those criteria applied to total concentrations of those contaminants. This finding was the impetus for Congress to amend the Clean Water Act in 1987 to address certain stormwater discharges, and thus became the primary justification for the US EPA and some states to develop control programs for contaminants in stormwater. It was also a major impetus for the US EPA's development of the National Toxics Rule (US EPA, 1992c).

This paper is a highly condensed version of a report by the authors, *"Water Quality Impacts of Stormwater-Associated Contaminants: Focus on Real Problems,"* (Lee and Jones-Lee, 1993a). This condensed paper reviews a number of issues related to defining and assessing the real water quality problems caused by contaminants in stormwater. The full report, available from the authors, also discusses the following issues: findings of concentrations of dissolved and total heavy metals in stormwater runoff, evaluation and regulation of heavy metals in stormwater runoff, public perception of stormwater quality problems and its influence on regulation, assessment of toxicity, eutrophication-related water quality problems caused by urban stormwater runoff, San Francisco Bay copper control program as example of problems with current approaches, sanitary quality of stormwater runoff, impact of channelization, control of contaminants at the source, and stormwater quality monitoring.

EVIDENCE FOR STORMWATER QUALITY PROBLEMS

In its publication entitled, "Environmental Impact of Stormwater Discharges a National Profile," the US EPA (1992a) stated,

> *"Based in part on national assessments conducted by the US Environmental Protection Agency (EPA) it is now recognized that nonpoint sources and certain diffuse point sources (e.g., stormwater discharges) are responsible for between one-third and two-thirds of existing and threatened impairments of the Nation's waters (US EPA, 1991)."*

More recently, the US EPA (1992b) stated in the Federal Register governing the proposed permit programs for "Phase II" dischargers, which included additional classes of stormwater discharges including smaller cities (but with the previously mentioned statutory exemptions),

> *"Over time, as the pollution control measures were implemented for these discharges* [domestic and industrial point-source wastewater discharges] *and as data collection efforts have provided additional information, it has become evident that more diffuse sources of water pollution, such as agricultural and urban runoff, are important contributors to water quality problems and use impairment."*

In the section of that *Federal Register* entitled, "Environmental Impacts," the statement was made,

> *"The Report* [US EPA Report to Congress] *indicates that roughly 30 to 40 percent of assessed rivers, lakes and estuaries are not supporting the uses for which they are designated. Based on the information from 51 States and Territories that reported on sources of pollution, the Report indicates that storm water runoff from a number of diffuse sources, including agricultural areas, urban areas, construction sites, land disposal activities, and resource extraction activities, is the leading cause of water quality impairment cited by States."*

A critical review of the US EPA "Report to Congress" upon which those quoted statements were based shows that it misrepresented the real water quality issues associated with stormwater-associated contaminant runoff from urban areas (see Lee and Jones-Lee, 1992a). In responding to the US EPA's request for information on this topic, the states indicated to the US EPA that what they were reporting as "water quality impairment" was in reality largely exceedances of water quality standards for certain parameters. Thus what was being reported was not, in fact, "impairment of designated beneficial uses of waters," but rather situations in which water quality standards, equivalent to US EPA worst-case or near-worst-case criteria, applied to the total forms of contaminants considered, were exceeded in surface waters.

The US EPA water quality criteria were developed using largely available forms of contaminants and assuming worst-case or near-worst-case exposure conditions for aquatic life. Thus, they are highly protective of sensitive aquatic organisms, and are overly protective when applied, as they are in many state water quality standards, to the total (rather than available) concentrations of the contaminants and largely independent of actual duration of organism exposure. While exceedances of water quality criteria and state standards numerically equal to them represent a violation of the Clean Water Act requirements, they do not of themselves represent an impairment of designated beneficial uses. The assessment of "impairment of beneficial uses" has to be made in terms that are reflective of the designated beneficial uses, specifically for aquatic life-related beneficial uses, the numbers, types, and character of aquatic organisms compared with what the habitat and other non-contaminant factors will allow. This definition is confused in some states, such as California, in which "impairment of designated beneficial uses" is defined for administrative purposes as an exceedance of a water quality objective (standard). Water quality management problems that can result from equating an administrative exceedance of a water quality standard with "impairment of designated beneficial uses" of a water are discussed by Lee (1993a,b) and illustrated in the section of this paper devoted to the current efforts to control copper input to San Francisco Bay from stormwater and other sources. In this paper, the phrase "impairment of beneficial uses" is used to mean exactly that, the impairment of the designated beneficial uses of a waterbody (e.g., aquatic life, domestic water supply, recreation, agricultural water supply, etc.).

The authors' conclusion that there are not, in fact, widespread water quality problems caused by stormwater-associated contaminants is supported by the results of a study funded by US EPA, Region V, devoted to evaluating urban runoff impacts on receiving waters. US EPA (1991) reported, in notable contrast to claims made by US EPA headquarters discussed above,

> *"While toxic metal criteria established from continuous exposure bioassays are regularly exceeded in stormwater, receiving water resources and local perception often do not reflect a corresponding beneficial use impairment of the resource. Possible reasons for this disparity are due to the conservative nature of water quality criteria designations and the complexity of biochemical cause and effect relationships. Instead, perceived or documented impairments focus on aesthetics from oil and floatable debris, species displacement from erosion/sedimentation in conveyance streams, and enhanced eutrophication potential from nutrient enrichment."*

APPLICABILITY OF WATER QUALITY CRITERIA AND STANDARDS TO REGULATING STORMWATER-ASSOCIATED CONTAMINANTS

The issuance of an NPDES permit for a discharge or runoff under Phases I and II of the US EPA stormwater quality management program sets forth an administrative process that ultimately leads to the assignment of a contaminant discharge load limitation. The allowed load is established at a level to meet water quality standards in the receiving water. In accord with US EPA criteria, those standards typically incorporate the requirement that the numeric standard not be exceeded more than once every three years. Those responsible for stormwater discharges from urban, industrial, and construction site areas have considerable, justified concern about the appropriateness of such application of the US EPA water quality criteria and state standards equivalent to them to the determination of the allowed contaminant discharge in stormwater. There will be few stormwater discharges that do not cause exceedances of state water quality standards for some chemicals in the vicinity of the discharge more than once every three years. Such exceedances would violate the NPDES permit and thereby trigger enforcement which would lead to reduction in the contaminant load from that source. The managers of that source would be obligated to initiate control/treatment programs to eliminate the violation.

Preliminary estimates of the cost for contaminant control from urban stormwater runoff from Phase I cities to achieve water quality objectives in receiving waters are several hundred billion dollars in capital costs plus annual operating and maintenance costs of similar magnitude (JMM, 1992). These figures translate to a cost of more than $1000/person/year in Phase I cities; without question this per capita cost would be substantially higher for those in many Phase II cities. With these kinds of costs, it had better be well-documented that such expenditures will, in fact, address real water quality problems rather than be used to eliminate the appearance of "administrative exceedances" of overly protective numeric standards.

ADDITIONAL WATER QUALITY CONCERNS

Most of the current concern regarding stormwater-associated contaminants is devoted to potentially toxic chemicals such as heavy metals in street drainage, which rarely cause impairment of the beneficial uses of waterbodies. As discussed by Lee and Jones-Lee (1993a), two groups of contaminants in urban stormwater runoff that are well-known to cause real water quality impairment, but that are not being reliably addressed by current management approaches, are aquatic plant nutrients (nitrogen and phosphorus) and pathogenic/indicator microorganisms. Excessive algae in lakes and reservoirs can cause water quality impairment through diminished aesthetic character, taste and odor and THM-precursor problems for water supplies, or oxygen depletion in hypolimnia. It is important to recognize, however, that aquatic plant nutrients are not, in themselves, of water quality concern; they are only of concern to the extent that they contribute to excessive growth of algae. Therefore, in the management of nutrient inputs to a waterbody, appropriate consideration has to be given to the availability of the nutrients and to waterbody-specific characteristics that govern how the nutrient load is manifested in algal biomass. As discussed by Lee and Jones-Lee (1993a), nutrients cannot be regulated reliably using numeric chemical-concentration criteria or standards. Jones and Lee (1986) and Lee and Jones (1988) discussed how reliable assessments can be made of the water quality impact of nutrient loads from point and non-point sources.

Water quality problems in surface waters are also caused by bacteria of fecal origin that are present in stormwater discharges/runoff. Typical stormwater, even that from separated stormsewers, has high concentrations of "fecal coliforms," a group of certain types of bacteria commonly present in fecal material of people and other warm-blooded animals. They are of concern because they are associated with human pathogens also found in human fecal material. "Fecal coliforms" or other indicators of fecal contamination are used as a basis for regulating contact recreational use of surface waters. Human fecal material can enter stormwater runoff by illegal connections and discharges of sanitary sewage to the stormsewer, and overflows from the sanitary sewerage system. Those sources, in addition to fecal material from urban animals (pets, etc.) can cause urban stormwater to be a potent source of fecal organisms to surface waters.

The nature of control programs for microbiological contaminants in stormwater is significantly different from that needed to control heavy metals. Based on the experience of the authors, some reduction in the frequency and extent of beach closures can be achieved by tightening the sanitary sewerage system and eliminating illegal discharges of sanitary sewage into the stormsewer system. However, it will be difficult to completely eliminate the presence of elevated levels of fecal organisms in stormsewer discharges. It is very important that the public and environmental groups understand that the current efforts directed toward the controlling chemical contaminants in stormwaters that cause violations of water quality standards will not solve the impacts of stormwater discharges on algae-related or sanitary quality of receiving waters.

SUGGESTED APPROACH FOR REGULATING CHEMICAL POLLUTANTS IN STORMWATER

The basic problem that exists with the current approach for evaluating and regulating stormwater-associated chemicals is that most do not recognize the differences between "contaminants" and "pollutants." As discussed by Lee and Jones (1990) by tradition "contaminants" are any materials added to water, while by tradition and law "pollutants" are contaminants that have an adverse impact on designated beneficial uses of a waterbody. The Clean Water Act requires the control of water pollution, i.e., impairment of beneficial uses of water. Thus the focus of water pollution control programs should be on those chemical forms that actually impair uses of water that are of concern to the public who have to pay for the control program.

In developing technically valid, cost-effective stormwater quality management programs it is important to recognize the nature of stormwater-associated contaminants and their differences from those typically associated with point-source discharges that affect their impact on beneficial uses of receiving waters. As demonstrated by the current situation of copper in San Francisco Bay, if the current approach followed for developing NPDES limitations is applied to stormwater discharges, hundred of billions of dollars will be wasted each year in treatment of "Priority Pollutants" in stormwater with little of no benefits to the designated beneficial uses of this nation's waters. At the same time, real water quality problems caused by aquatic plants nutrients from non-point sources are being inadequately addressed. The approach that the authors recommend for regulating priority pollutants is outlined below.

For Existing Stormwater Discharges:

1. Identify Specific, Real Water Quality Problem (Impairments of Beneficial Use) in the Waterbody in the Vicinity of the Discharge

2. Determine the Cause(s) of the Problem (Specific Chemical Contaminant(s), Source of Contaminants, or Physical, Meteorological, or Biological Condition(s))

3. If Problem Not Caused by Physical, Meteorological, or Biological Conditions, Determine the Chemical Contaminant(s) Likely Responsible for Problem

4. Determine the Sources of the Pollutant(s) with Particular Reference to Stormwater Discharges. Of particular concern for Urban Stormwater Runoff is to Determine If There are Any Illegal or Illicit Discharges/Connections Contributing the Pollutants.

   If More Than One Source Exists for the Pollutant(s), Determine the Proportionate Contributions of Each to the Water Quality Problem (Considering Such Issues as Availability/Toxicity of Forms of Contaminants from Each Source).

5. Verify Responsibility of Chemical(s) and Determine Level of That Chemical(s) That Would Not Elicit Adverse Impact on Beneficial Uses of That Waterbody

6. Determine the Allowable Load of the Contaminant(s) to the Waterbody to Achieve Concentration Determined in Step 5

7. Develop an Allocation of Pollutant Loads from Each Source That Can Be Controlled to Achieve Load Determined in Step 6

8. Evaluate the Improvement in Designated Beneficial Uses That Will Occur If Control Program Is Implemented

9. Determine the Total Costs of Control of Pollutant(s) from Each Source

10. Determine and Describe the Societal Benefits to Be Derived Spending the Required Funds for Control of Pollutant(s)

11. Implement Societally Appropriate Pollutant(s) Control Program

12. Monitor Receiving Waters for Impacts and Adjust Contaminant(s) Limitations at Triennial Reviews

For Proposed New Stormwater Discharges

1. Assume Plausible Worst-Case Scenario for Exposure of Sensitive Organisms to Contaminants in Proposed Discharges; Use Reliable Aqueous Environmental Chemistry and Toxicology Information in a Site-Specific Hazard Assessment Framework to Establish Discharge Limitations

2. Monitor Receiving Waters for Impacts and Adjust Contaminant(s) Limitations at Triennial Reviews

Conflict is developing between point source and non-point source dischargers over their relative contributions to "water quality impairment." In many of those situations in which concentrations of total recoverable metals are used to implement US EPA criteria and state standards, it is often found that non-point-source dischargers represent by far the greater source of metals that cause the water quality standards violations. However, those distinctions have little to do with the relative contribution to real water quality problems.

The basic problem in this conflict is that the focus has not been on the cause of real water quality problems caused by the discharges/runoff, but rather the point source and non-point source dischargers and regulators are focusing on violations of overly protective water quality standards and the contributions of those sources to those "violations." As discussed elsewhere herein, this is an artifact of the way in which the Clean Water Act is implemented at the local level. By focusing on effluent concentrations and allowed dilution of permitted loads, it is relatively straightforward to detect "violations." If, however, the focus were on receiving water quality impacts of discharges, those discharges contributing to the problem would be the focus of control programs. If the listing above were adopted by point source and non-point source dischargers and the regulatory agencies responsible for them, the basis for this conflict between point source and non-point source dischargers should disappear. Irrespective of the source(s) of contaminants that impair beneficial uses of receiving water, the funds provided by the public either directly or indirectly should be used to solve real water quality problems rather than squandered on addressing administrative exceedances that are artifacts of overly protective standards.

The approach suggested above for evaluating and addressing water quality problems caused by non-point source discharges will require that those responsible for those discharges/runoff spend funds for studies of ambient waters potentially impacted by their discharges. In many cases, point source and non-point source dischargers have not conducted such studies, and in fact, are reluctant to undertake such studies. Studies of this type represent a change in philosophy of approach and funding. The traditional approach is to focus only on effluent/discharge characteristics rather than ambient waters. The effluent/discharge is easy to sample, and the "interpretation" of the results is done by mechanical comparison with permit limitations. Such "interpretation" does not demand significant understanding of aqueous environmental chemistry or aquatic toxicology. On the other hand, properly conducted studies of ambient water quality characteristics (as related to beneficial uses) and the impact of the discharge on those characteristics requires a high degree of competence in aqueous environmental chemistry and aquatic toxicology, and an ability to work with regulators to develop technically valid, cost-effect control measures.

STORMWATER QUALITY MANAGEMENT

Stormwater quality management entities are in the process of developing contaminant control programs for Phase I stormwater discharges. Those programs typically initially focus on the implementation of "best management practice" (BMP). A variety of guidance manuals for BMP's for stormwater have been developed and are under development by various professional groups and regulatory agencies (MWCOG, 1992; APWA, 1993; WEF, 1993). Lee and Jones (1991) and Lee and Jones-Lee (1992b) discussed the importance of focusing BMP's on real water quality problems caused by the particular discharge for the particular site of focus. At the urging of environmental groups, Congress specified in the 1972 Clean Water Act that all municipalities provide a standard basic degree of treatment for domestic wastewaters ("secondary" treatment) irrespective of the indications of the need for such treatment to protect beneficial uses of a particular receiving water. That approach should not be followed to direct the construction of contaminant control systems for stormwater discharges.

One of the common BMP approaches to "controlling" contaminants in stormwater discharges is the construction of detention basins on the discharges to effect a decrease in concentration of chemical contaminants later discharged to receiving water. While such facilities cause settlement of some of the larger particulates, contaminant forms associated with those detained particulates are largely unavailable to cause toxicity to aquatic life; detention basins allow the passage of dissolved contaminants that could adversely affect aquatic life. Thus, as discussed by Lee and Jones (1991) and Lee and Jones-Lee (1992b), the construction of detention basins on stormwater discharges are largely ineffective in controlling real water quality problems that may be caused by stormwater-associated contaminants.

Not only are detention basins largely ineffective in controlling water quality problems in waters receiving stormwater drainage, but also there is increasing concern about the potential problems associated with management of particulate matter that is collected in them. Stormwaters from urban areas typically contain elevated concentrations of particulate forms of contaminants such as lead, much of which will settle out in a properly designed, operated, and maintained detention basin. The assessment of lead-contaminated soil, sediment, or waste for its classification as "hazardous waste" was originally made based on the results of EP-Tox test and is now made based on the results of the US EPA's TCLP test. The prescribed basis for establishing the allowed level of lead that can be leached in the TCLP test procedure without the tested material's being classified as "hazardous waste" is the drinking water standard of 50 μg/l, multiplied by a factor of 100; on that basis, 5 mg/l lead is allowed to leach from the soil, sediment, or waste under the test conditions before the material is classified as a "hazardous waste" and in need of management as such. The US EPA and some state regulatory agencies have recently reduced the accepted concentration of lead in drinking water to 15 μg/l. This change would be expected to cause a substantial reduction in the amount of leachable lead that would "pass" the TCLP, and cause more materials to be classified as "hazardous waste." It will likely be found that some soils that accumulate in stormwater detention basins will contain sufficient amounts of lead to be classified as "hazardous waste." Further, the 15 μg/l drinking water action level may be further decreased to the 5 μg/l level that the US EPA proposed several years ago in response to increased understanding about the levels of blood-lead that can cause human health problems. That decrease could decrease the allowed leachable lead in TCLP tests by a factor of 10 below its current level, before a material would be classified as "hazardous waste." There are many urban soils that leach lead under TCLP conditions to generate leachate concentrations above 0.5 mg/l. Therefore those responsible for operation and maintenance of stormwater detention basins could find themselves in the position of having to manage the collected solids as "hazardous waste." This increases the cost of disposal from a few tens of dollars per ton to a few hundred dollars per ton for management in a "hazardous waste landfill."

Another approach that is often considered to be BMP for stormwater-associated contaminants is the construction of infiltration basins to promote the passage of stormwaters into the groundwater aquifer system. In the past, the construction of infiltration basins has been done with little or no regard for the potential for groundwater pollution by contaminants in the stormwater. Lee and Jones-Lee (1993b) discussed the importance of the proper evaluation of the potential for groundwater pollution by contaminants in waters that are directly or incidently introduced into groundwaters.

The first step that should be taken in defining a BMP is to define the specific water quality impairment being caused by stormwater-derived contaminants. As noted above, the authors have yet to find a documented aquatic life toxicity problem caused by stormwater discharges to receiving waters that was not due to illegal or illicit disposal/connections. Thus, as discussed by Lee and Jones (1991) and Lee and Jones- Lee (1992b) if a real water quality problem is identified, the first "BMP" that should be undertaken is the careful examination of the system for illegal or illicit disposal or connections of industrial or commercial waste to the stormwater system. If possible, the contaminants should be controlled at the source. For example, studies have revealed that lead in urban stormwater drainage is contributed from a variety of sources. Of particular importance are automobile exhaust residues presently in soils. Gasoline to which lead had been added in years past contained one to three grams of lead per gallon or about 300 mg Pb/l. The combusted lead products, emitted in the exhaust as particulate lead compounds, largely settled within a kilometer or so of the source of emission; some of the finely divided particulates were carried long distances in the air (Lee and Jones-Lee, 1992c). According to Robertson (1993) today's gasoline can contain up to 17 mg/l and still be classified as "unleaded" gasoline; he reported that today's gasoline typically contains about 10 mg/l lead as a natural contaminant of gasoline. Diesel fuel also contains potentially significant amounts of heavy metals. Therefore residues being generated today from gasoline and diesel fuel are still contributing lead to stormwater runoff. Mangarella (1992) reported that vehicle fuels are important sources of lead, mercury, zinc, silver, and copper for stormwater runoff in the Santa Clara Valley, CA. He also reported that automobile brake pads are important sources of copper in stormwater runoff. Tire wear was found to be an important source of cadmium and zinc in stormwaters.

The finding that certain automobile/truck components and fuels are important sources of heavy metals and other chemicals of potential concern in stormwater runoff has started calls for modifying the composition tires, gasoline, diesel fuel, and brake pads. In developing heavy metal control programs for stormwaters it is important to focus on those sources that contribute forms of heavy metals and other contaminants that actually impair beneficial uses of receiving waters, on a waterbody-specific basis. If it is found that the sources of heavy metals such as gasoline, diesel fuel, tire wear and brake pads are contributing forms of metals to stormwaters that actually impair beneficial uses of receiving waters, consideration should be given to trying to control those sources contributing those heavy metals to the extent possible. If, as expected, the copper in brake pads, the residual lead and copper in gasoline and diesel fuel, and the cadmium and zinc in tires are present in stormwater in forms that are unavailable/non-toxic, then the ban or modification of these products to reduce the metals concentrations in stormwater will have no impact on water quality and could be strongly detrimental to the interests of the public. In addition to the costs of development and use of substitute products, there could well be real environmental, public health, or other adverse impacts caused by the substitute products. As discussed by Lee and Jones-Lee (1993a), the public needs to be given reliable technical information about those sources; there have been public information travesties that have resulted in emotion-based, technically unreliable management decisions about the control of contaminants in the past.

Only after the sources of contaminants in stormwater runoff that are having adverse impacts on beneficial uses of receiving waters have been evaluated and addressed, and only if those measures have not caused resolution of the water quality impairment, should consideration be given to structural treatment options for the stormwater runoff. Treatment should focus on those components of the stormwater responsible for the specific water quality impairment of the particular receiving water. Because the stormwater-associated contaminant(s) that may cause an impairment of a beneficial use would be site-specific, and because of the rarity of aquatic life toxicity caused by urban stormwater runoff not due to illegal or illicit disposal or connections, a "standard" off-the-shelf BMP cannot be prescribed for stormwater runoff treatment. For example, detention basins should not be constructed if there are no impairments of beneficial uses in the receiving waters caused by those materials that would be removed in such a facility at the site in question, i.e., a portion of the large solids. If those materials are causing demonstrated impairment of beneficial uses of receiving waters, careful attention needs to be given to the site-specific conditions since in general the greatest sediment transport from erosion occurs during very short periods each year of very high flows. Stormwater detention basins are often not designed to retain particulates under high flow conditions. Thus while a detention basin may function well under low or moderate flow conditions, it may fail to manage those contaminants contributed during high flows that are in fact of water quality significance.

CONCLUSIONS

Non-point source discharges/runoff typically contains sufficient levels of chemical contaminants to cause exceedances of water quality criteria/standards applied to total concentrations in the receiving water.

It is known from aqueous environmental chemistry that many contaminants exist in aquatic systems in a variety of chemical forms, only some of which are available/toxic to aquatic life. Thus the total concentrations of those chemicals in a water are poor indicators of the concentrations that are available to be toxic/available to impact designated beneficial uses of waterbodies.

Because of the short-term, episodic nature of stormwater discharges to receiving waters, the concentrations of contaminants can typically exceed the US EPA water quality criteria in the receiving water without adverse impacts on beneficial uses of the waterbody.

Contrary to statements made by some within the US EPA, the exceedance of a numeric US EPA water quality criterion or state standard equivalent to it applied to the total concentration of the contaminant is not equivalent to an impairment of the designated beneficial use of the waterbody.

What are often cited as "problems" allegedly caused by stormwater discharges (exceedances of numeric criteria/standards) are not in fact water quality impairment, but rather are artifacts of the overly protective criteria and standards that do not properly consider the aqueous environmental chemistry and toxicology of stormwater-associated contaminants in surface waters.

Site-specific evaluation must be made of the availability/toxicity of stormwater-associated contaminants in light of the duration of organism exposure in the receiving water, in order to develop technically valid, cost-effective contaminant control programs.

Because of the high costs of structural treatment of non-point source discharges, before end-of-pipe runoff control programs are undertaken the real water quality problems (use-impairment) caused by the stormwater runoff should be identified and the improvement expected in beneficial uses to result from the treatment works defined.

Where beneficial use impacts are found to be caused by stormwater discharge/runoff, many can be addressed through source control of illegal and illicit discharge/connections.

BMP's for stormwater discharges/runoff should focus on controlling real water quality problems (use-impairment) in the receiving water caused by the discharges/runoff, on a site-specific basis.

Structural BMP's will rarely be needed to control "Priority Pollutants" in urban stormwater discharges.

Fecal organisms in sewer-separated urban stormwater discharges adversely impact the use of receiving water for contact recreational purposes.

Aquatic plant nutrients (nitrogen and phosphorus) in non-point source discharges/runoff can cause real water quality problems (use-impairment) in the nation's surface waters.

Methodology is available today to evaluate, on a site-specific basis, whether nutrient control programs for urban stormwater will be effective in controlling excessive fertilization and related water quality problems caused by a particular stormwater discharge.

Phosphorus evaluation and control programs for stormwater discharges should focus on available forms.

Stormwater quality monitoring programs should focus on finding significant, real water quality problems (use-impairment) and on detection and control of illicit and illegal discharges and connections of available/toxic forms of contaminants.

Combined sewer overflows can cause real water quality problems and deserve special attention so that adequate containment/treatment of the CSO is accomplished before discharge.

REFERENCES

APWA (American Public Works Association) (1993). Best management practices for storm water permit compliance. American Public Works Association, Chicago, IL.

JMM (James M. Montgomery Consultants) (1992). A study of nationwide costs to implement municipal stormwater best management practices. Final report to Water Resources Committee, American Public Works Association, Southern California Chapter, APWA, Chicago, IL.

Jones, R. A. and Lee, G. F. (1986). Eutrophication modeling for water quality management: an update of the Vollenweider-OECD model. World Health Organization's Water Quality Bulletin 11(2), 67-74.
Lee, G. F. (1993a). Letter to P. Lloyd, Chairperson, San Francisco Bay Regional Water Quality Control Board, from G. Fred Lee, February 1.
Lee, G. F. (1993b). Letter to P. Lloyd, Chairperson, San Francisco Bay Regional Water Quality Control Board, from G. Fred Lee, February 25.
Lee, G. F. and Jones, R. A. (1988). The North American experience in eutrophication control through phosphorus management. In: *Proc. Internat. Conference on Phosphate, Water, and Quality of Life*, Paris, France.
Lee, G. F. and Jones, R. A. (1990). 'Contaminant' versus 'pollutant': Need for US EPA and state water pollution control agency policy in developing control programs for aquatic life toxicity. Report of G. Fred Lee & Associates, El Macero, CA. October.
Lee, G. F. and Jones, R. A. (1991). Suggested approach for assessing water quality impacts of urban stormwater drainage. In: *Symposium Proceedings on Urban Hydrology*, American Water Resources Association Symposium, November 1990. Technical Publication Series TPS-91-4, AWRA, Bethesda, MD. pp. 139-151.
Lee, G. F. and Jones-Lee, A. (1992a). Comments on National Pollutant Discharge Elimination System, Request for Comment on Alternative Approaches for Phase II Storm Water Program; Proposed Rule September 9, 1992 *Federal Register* 40 CFR Part 122. Submitted to the US EPA, Washington, DC.
Lee, G. F. and Jones-Lee, A. (1992b). Development of technically valid, cost-effective control programs for stormwater-associated contaminants. Presentation to American Public Works Association/State Water Resources Control Board Stormwater Quality Task Force, September.
Lee, G. F. and Jones-Lee, A. (1992c). Importance of considering soil-lead in property site assessments. Proc. National Ground Water Association Conference, Environmental Site Assessments: Case Studies and Strategies, Orlando, FL. August.
Lee, G. F. and Jones-Lee, A. (1993a). Water quality impacts of stormwater-associated contaminants: Focus on real problems. Report of G. Fred Lee & Associates, El Macero, CA. March.
Lee, G. F. and Jones-Lee, A. (1993b). Water quality aspects of incidental river groundwater recharge of domestic and industrial wastewaters. Presentation at AWRA 29th Annual Conference on "Innovations in Ground Water Management" and Symposium "Effluent Use Management." Tucson, AZ. August.
Mangarella, P. (1992). Source identification and control - Santa Clara Valley nonpoint source pollution control program. Source Identification and Control Report Prepared by Woodward-Clyde Consultants, Oakland, CA. December.
MWCOG (Metropolitan Washington Council of Governments) (1992). A current assessment of urban best management practices; techniques for reducing non-point source pollution in the coastal zone. MWCOG, Washington, D.C. March.
Robertson, W. (1993). Letter to the Editor and Personal Communication, Environmental Protection 4, 64.
US EPA (1990). National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges; Final Rule. *Federal Register* 55(222), 47990-48091. November 16.
US EPA (1991). Urban runoff impacts to receiving waters. US Environmental Protection Agency, Watershed Management Unit, Water Division, Region V, Chicago, IL.
US EPA (1992a). Environmental impacts of stormwater discharges, a national profile. EPA 841-R-92-001, US EPA Office of Water, Washington, D.C., June.
US EPA (1992b). National Pollutant Discharge Elimination System, Request for Comment on Alternative Approaches for Phase II Storm Water Program; Proposed Rule. 40 CFR Part 122, *Federal Register*.
US EPA (1992c). Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance; Final Rule," 40 CFR Part 131, *Federal Register* 57(246), 60848-60923.
WEF (Water Environment Federation) (1993). Urban stormwater quality management. Water Environment Federation Technical Practice Committee - Urban Runoff Task Force report. Alexandria, VA.